Homework Assignment 3

25 Science, Philosophy, and the Big Questions — due 3 February 2012

For submission

Read the introduction and first two sections of Einstein's paper 'On the electrodynamics of moving bodies' available at `http://www.pitt.edu/~jdnorton/teaching/HPS_0410/assignments/04_origins/On-the_electrodynamics/index.html`. Read it slowly and reverently. This text is to modern physics what Genesis is to modern Judeo-Christianity and the Declaration of Independence is to US history.

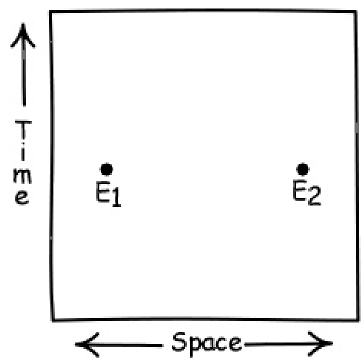
1. Compare what is moving with respect to what in the magnet and conductor thought experiment in the two accounts you have: the one Einstein gives in his paper `http://www.pitt.edu/~jdnorton/teaching/HPS_0410/assignments/04_origins/On-the_electrodynamics/index.html` and the one in the chapter section 'Magnet and conductor' at `http://www.pitt.edu/~jdnorton/teaching/HPS_0410/chapters/origins_pathway/index.html#Magnet`. How do the two accounts differ?

2. What is the definition of 'simultaneity' that Einstein describes in the first section of his paper? That is, what must be stipulated by definition according to Einstein if we are to be able to compare the timing of events at a point A and a point B of space?

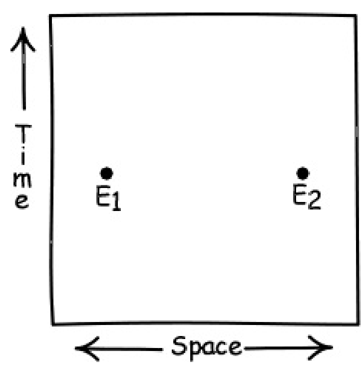
3. Draw a spacetime diagram with the following elements. Be sure to label each one clearly.
   (a) An event O.
   (b) A worldline of an observer A that passes through O.
   (c) The light cone at O.
   (d) The hypersurface of all events simultaneous with O (for observer A).
   (e) An event Epast which is in the past of O and can causally affect O.
   (f) An event Efuture which is in the future of O and can be causally affected by O.
   (g) An event Eelsewhere which is outside the light cone of O and cannot be causally affected by O.
   (h) A timelike curve through O.
   (i) A spacelike curve through O.
   (j) A lightlike curve through O.

4. On the spacetime diagrams below:

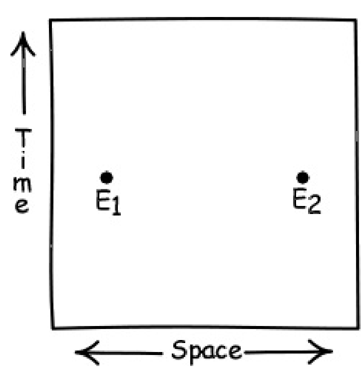
(a) An observer A judges the two events E_1 and E_2 to be simultaneous. Draw the worldline of the observer A and a hypersurface of events that A will judge to be simultaneous. How does this hypersurface support A's judgment of the simultaneity of E_1 and E_2?



(b) An observer B moves relative to A and judges E_1 to be later that E_2. Draw the worldline of observer B and a hypersurface of events that B will judge to be simultaneous. How does this hypersurface support B's assessment of the time order of E_1 and E_2?



(c) An observer C moves relative to A and judges E_1 to be earlier that E_2. Draw the worldline of observer C and a hypersurface of events that C will judge to be simultaneous. How does this hypersurface support C's assessment of the time order of E_1 and E_2?



(d) If C judges a tachyon to have travelled from E_1 to E_2, what would A and B say about it?

For discussion in the recitation

A. In the introduction, what is established by the magnet and conductor thought experiment? How do ether current experiments enter the discussion? What is 'apparently irreconcilable' and why is it so? How is Einstein suggesting that he will solve the problem?

B. In Section 2, how does Einstein establish that observers in relative motion may disagree on the lengths of rods and the synchrony of clocks?

C. If the synchrony of different clocks is set by a definition, presumably freely chosen, then it would seem that any velocities measured by them are also a matter of freely chosen definition. So how can Einstein at the end of Section 1 say that the constancy of the speed of light is a universal constant 'in agreement with experience'?

Here are some questions about $E=mc^2$:

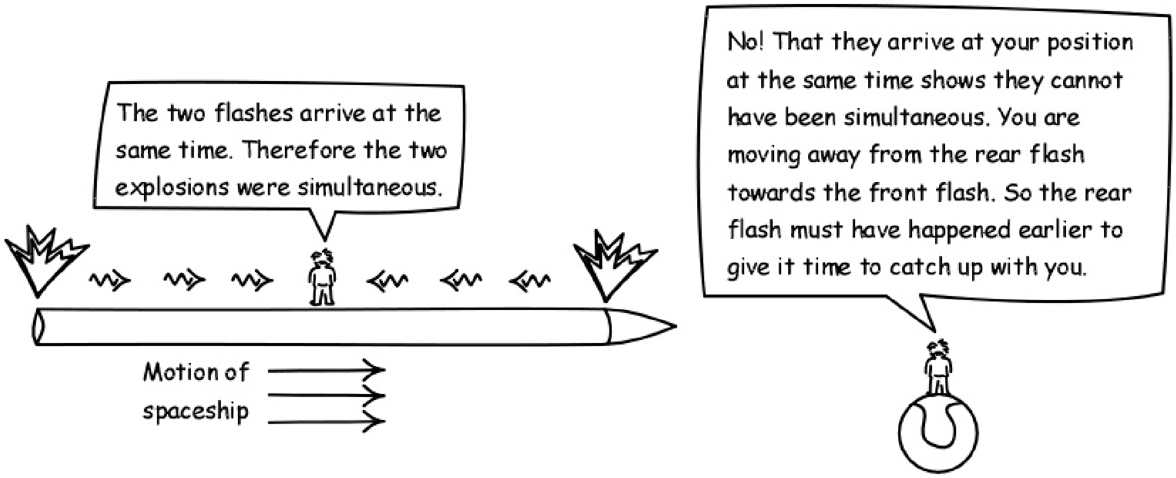
D. What does the law of conservation of mass say? What does the law of conservation of energy say? In classical physics, these are two separate laws. What becomes of them in relativity physics?

E. When an electric battery is charged, what happens to its mass? When a hot body cools, what happens to its mass? When a spring is compressed what happens to its mass? Inside a completely isolated spacestation, an electric battery is used to warm the hands of an astronaut and to run a motor that winds a spring. What happens to the total energy of the spaceship? What happens to the total mass of the spaceship?

F. When an atom of Uranium-235 undergoes fission and breaks into parts, the total mass of the parts is less than the mass of the original atom. What happens to the missing mass? Why is this missing mass important in modern life? What does the law of conservation of mass say? What does the law of conservation of energy say? In classical physics, these are two separate laws. What becomes of them in relativity physics?

Some questions about spacetime:

G. The relativity of simultaneity is revealed most simply in the following thought experiment in which two observers in relative motion judge the timing of two explosions by means the light signals they produce:



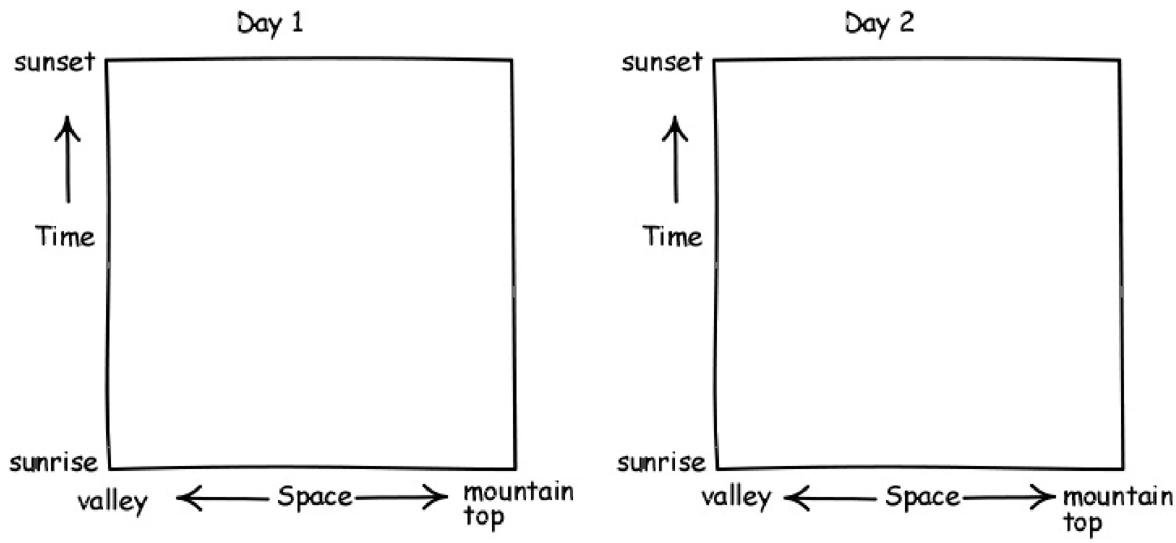
Draw a spacetime diagram of this experiment, indicating:

- The planet observer's worldline and associated hypersurfaces of simultaneity.
- The spaceship observer's worldline and associated hypersurfaces of simultaneity.
- The worldlines of the front and rear of the spaceship.
- The two explosion events.
- The light signals emitted by the explosions.

H. At sunrise of Day 1, a monk commences a long walk up the narrow, winding road from the monastery in the valley to the mountain top. It is a hard, tiring climb, so he stops frequently to rest and even reverses his direction from time to time. He arrives at the mountain top just at the moment of sunset. At sunrise on Day 2, the monk commences the return journey. This time the journey is far easier. Rather than hurry to complete it quickly, the monk decides to pause frequently to admire the wildflowers, inhale the mountain air and absorb the splendor of the view. He arrives in the valley at the moment of sunset.

Is there any moment on the two days at which the monk is in exactly the same position on the road?

At first it seems impossible to determine an answer to this question from the information given. Whether there is such a moment seems to depend on the details of the monk's progress up and down the mountain. Drawing spacetime diagrams rapidly solves the problem, however. To see how, draw plausible world lines for the monk's two journeys on the spacetime diagrams here.



Explain how they make it obvious that the moment specified in the question must always exist no matter what the details of the monk's progress. (Hint: To see this, imagine the two spacetime diagrams superimposed.)